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ABSTRACT

In contrast to the rigid forms of scientific textbooks and research reports, the examples of scientific writing discussed in this paper demonstrate a regard for human values within science and provide a rationale for introducing students to a variety of scientific writing as part of their educational experience. The paper states that not all scientific thought or writing is technical or difficult to understand, and that in fact, the wide range of purposes, structures, and styles in scientific writing is something that high school and college students should learn to appreciate. The paper suggests that by reading beyond the science textbook, students will discover that scientists are not a race apart, unconcerned about the effects of their work on others, but that they wield their enormous power only at the will of society, and that conscientious scientists strive to communicate. (RL)

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SCIENTIFIC WRITING BEYOND THE TEXTBOOK

Alice F. Randall

Because scientific thought is generally believed to find its expression in language that is technical, if not arcane, it is something of a revelation to discover the extraordinarily wide range of scientific writing. Indeed, in no other field does there appear such variety of purposes, structures, and styles. The objective of this paper is to identify some gifted authors whose scientific writing demonstrates their regard for human values and to investigate the rationale for introducing students to a variety of scientific writing as an important contribution to their educational experience.*

To be sure, technical terminology and a fairly uniform format dominate the writing in textbooks and research reports in the journals. Textbooks tend to be closely organized descriptions of structure, function, and process. They are written crisply and concisely, deliberately sacrificing drama, human interest, and eloquence to clarity; but the concession to clarity results in presenting past research as fact, beyond speculation and discovery for the reader. Jacques Barzun complains that, "the schools enforce upon all above the elementary grades a 'science requirement,' which turns out to be largely wasted on three-quarters of those subjected to it. They leave school and college remembering of science only tedium and difficulty."[1] That there is a rationale for the prescribed textbook form is explained by the author of a physical chemistry text:

*All of the works cited in this paper are intellectually and linguistically accessible to the college student, whatever his scientific background, and many of them are readable at the high school level. Accompanying the paper is a book list that is stimulating but by no means comprehensive. Readers will wish to supplement it with their own favorites.

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..."The subject is presented in a mathematically rigorous way... The justification for a rigorous treatment is pedagogical; it makes the subject simpler".[2] But Barzun argues that,

> "all the subjects in which the thinking public takes an interest are in effect treated philosophically and historically... The same possibility exists for science to be judged and appreciated--indeed to be enjoyed. And this possibility will have to be realized, with the aid of competent interpreters, if science is ever to become a part of the public consciousness in the same sense as art, history, religion, and philosophy".[3]

Professional journals also apply structural conventions. Their accounts of current research combine sufficient technical detail to allow for replication and knowledgeable criticism, with brevity necessitated by the enormous volume of new research and the tentative status of new findings not yet incorporated into major theories.

Supra-technical Writing by Scientists

It is the first-hand, lengthier accounts of the process leading to a discovery that provide the reader with a view of the scientific mind at work; and, accompanying the mental activity, the failures, competition, disappointment, excitement, creative insights, even accidents that provide a fertile mind with hints of a relationship between seemingly disparate observations. Significant discoveries have been recounted in detail by scientists who made them. Louis Pasteur wrote volumes describing, with some attractive personal asides, his experiments with fermentation. In The Voyage of the Beagle, Darwin's scientific journal cum travelogue, the sharpening of his faculties for scientific observation is evident. James D. Watson's The Double Helix recounts the theoretical, personal, and political ambushes and achievements of the Watson-Crick team in pursuit of the model of the structure of DNA.

Other scientists write expository accounts of collective research in an impulse to share their exhilaration. "Scientific ideas have tremendous beauty. They have a daring beyond any that is found in other branches of human endeavor,"[4] writes one. Part of the "charge" issued to the scientists who wrote a National Academy of Science survey of life sciences in 1970 was: "If it is to be successful, the report must convey a sense of the excitement and enthusiasm of the practitioners of our disciplines."[5] The best of these accounts present ideas in accessible form without claiming that they will be easy reading. Einstein's Relativity, planned as a simplified version of The Special and General Theory of Relativity, is more formidable because of its mathematical content than, say, Gerald Feinberg's recent book, What Is The World Made Of? Atoms, Leptons, Quarks, and Other Tantalizing Particles or Steven Weinberg's The First Three Minutes (about whose title the author engagingly remarks, "The First Three Minutes sounded better than The First Three and Three-Quarter Minutes.")[6]

Many scientists whose interests are social and humanitarian as well as technical combine persuasion with exposition in their writings, which are commonly more eloquent than popularizations. Their thinking embraces the larger human issues of which science is an integral component, and their perception of science aspires toward greater depth than strictly technical scientific thinking, whether their vehicle be social commentary, biography, or history. Their style can be literate, imaginative, sometimes lyrical. Jacob Bronowski's Science and Human Values, analyzing the homage of the scientist to the most esteemed values of the human race, is still a text in many humanities courses. More recently, Lewis Thomas' The Lives of a Cell: Notes of a Biology Watcher became not only a bestseller but the object of acclaim by such non-scientists as John Updike and Joyce Carol Oates, who used

it in her literature classes. A pathologist, president of the Sloan-Kettering Cancer Center, Thomas is interested in the entire eco-system and is devoted to the best in the human species. Speculating about communication with remote space life, he writes,

> "Let us assume that there is, indeed, sentient life in one or another part of remote space, and that we will be successful in getting in touch with it. What on earth are we going to talk about?...Perhaps the safest thing to do at the outset, if technology permits, is to send music. This language may be the best we have for explaining what we are like to others in space, with least ambiguity. I would vote for Bach, all of Bach, streamed out into space, over and over again. We would be bragging, of course, but it is surely excusable for us to put the best possible face on at the beginning of an acquaintance."[7]

No doubt Dr. Thomas is gratified by the inclusion of Bach in the communication capsule sent into outer space in September of 1977.

Again in Rene DuBos the reader discovers a scientist who writes with astonishing simplicity of the relationship of man to all creation. Harlow Shapley can be read for the intimate conflation of astronomical data and their social implications.

The dissident Soviet scientists make a passionate appeal for the consideration of human values in scientific enterprise. Andrei Sakharov, for example, concludes a treatise on the dangers to and hope for mankind's survival with this affirmation: "If..an all-encompassing scientific and technological revolution, promising uncounted benefits for mankind, is to be possible and safe, it will require the greatest possible scientific foresight and care and concern for human values of a moral, ethical, and personal character."[8]

In the editorials and articles of the major scientific journals, the eloquent voices of concerned scientists are heard regularly, issue after issue. (Not always the voices of wisdom alone, they sometimes reflect all-too-human

self-consciousness, doubt, and even guilt.) Editorials in the journal of the AAAS, Science, stress the relation of science to politics, public attitudes, and the economy, and comment on the future of research and scientific education. Articles in Science and other journals provide explicit details of the political implications of scientific enterprise, relationships between science and both the executive and legislative branches of government, and the effects of scientific research on life-style. For example, Wallace Cloud described in detail in The Sciences in November 1973 the disastrous consequences of oil spills and the hope implied in rising public consciousness and government/industry action toward their control.[9]

Biologists turned social critics often find themselves compelled to speak out on ethical questions related to ecology. Paul Ehrlich traces their developing concern in an editorial for BioScience:

> "It is probably fair to say that the vast majority of professional ecologists today did not choose that field out of a desire to save the world. They were interested in natural history, in a particular group of organisms, or in the fascinating problems of how the different organisms of our planet interact with each other and the physical environment...But now environmental problems have moved toward the center of the world stage and professional ecologists are faced with a series of ethical dilemmas. Perhaps the most basic can be simply phrased as 'Should I get involved?' Is it 'responsible' for a scientist to make public statements in areas outside of his or her discipline? Obviously I think it is... For me and many of my colleagues, whether or not to speak out as a scientist poses no ethical dilemma at all."[10]

The grande-dame of ecologists, Rachel Carson, has little need to enter a plea; her descriptions and photographs of areas she has known and loved well enchant the reader into an attitude of believing that the preservation of the delicate balance of nature is a deserving enterprise. Victor Scheffer performs a similar service in such works as The Year of the Whale, which beguiles the senses as well as the mind. In The Living Sea and World Without

Sun Jacques-Yves Cousteau is also content to eschew polemics as he narrates exciting adventures of undersea exploration and colonizing. Elsewhere he exhorts or ponders: for instance, in negating the infallibility of scientific technicians he quotes Prometheus,

> "How weak is Science
> Confronted with Destiny." [11]

Barry Commoner and Paul Ehrlich are perhaps the most prominent of scientists who portentously urge their readers to observe and preserve environmental balance, but they are not alone. In pleading the same cause the zoologist Marston Bates displays a fine lucidity. He writes that in the Western, Christian Tradition "the material universe is completely man-centered. Animals are unimportant because they have no souls. God may notice the sparrows, but this is an example of his omniscience rather than of his preoccupation..."[12] He pleads, however, for an more expansive ethical concept: "Life is a unity; the biosphere is a complex network of interrelations among all the host of living things. Man, in gaining the godlike quality of awareness, has also acquired a godlike responsibility."[13]

Besides social criticism, the humanist-scientists write biography and history. Meeting high literary standards in autobiography are Max Born and Albert Einstein, whose experiences, both professional and personal, lead to persuasive social theory and high human aspirations. Scientists who write biographies of other scientists are authoritative and often eloquent (for example, DuBos in Louis Pasteur--Free Lance of Science). Readable historical accounts of scientific development include George Gamow's Biography of Physics and the Einstein-Infeld The Evolution of Physics, whose theme is summarized on their final page : "Without the belief that it is possible to grasp the

reality with our theoretical constructions, without the belief in the inner harmony of our world, there could be no science."[14]

With the humanistic scientist-writers are those who address both the scientist and non-scientist to plead the philosophical implications of their work. It is not surprising, given the strength of his sentiment toward the layman's acquisition of a concept of science, that Einstein expresses the concern most dramatically: "...the eternal mystery of the world is its comprehensibility."[15] Loren Eiseley, too ponders on the mysteries of man and nature which are enhanced, not diminished, by the considerable knowledge he has accumulated on the development of man.

Three of the four scientific books included in Mortimer Adler's list of "Classics" of 1945 to date are philosophical works by Werner Heisenberg; the fourth is Jacques Monod's Chance and Necessity.[16] Stephen Toulmin deserves special attention because his training and experience qualify him in both science and philosophy. He is also a lively writer whose clarity and earthiness induce the reader to delight in his revelations:

> "We now have a number of general notions and principles which make sense of the observed regularities, and in terms of which they all hang together. Think how different Kepler's laws of planetary motion appeared after Newton. Kepler discovered that the orbit of Mars was, as near as he could tell, elliptical. He had some ideas of his own about the forces responsible for the planetary motions, but these provided no compelling reason why the orbit should have just the shape it did. So, the elliptical shape of the orbit was, for him, just a tiresome, obstinate, and arbitrary fact--'one more cartload of dung,' which had to be brought into his system, 'as the price for ridding it of a vaster amount of dung.' Newton, by contrast, gave us a whole new set of conceptions, in terms of which Kepler's regularities ceased to appear as arbitrary facts. In the new theory, they all made sense and hung together, granted only a few plausible suppositions. Kepler told us: such-and-such is in fact the case. Newton showed us that, if we only supposed so-and-so, then on his principles Kepler's facts must be as they are." [17]

Scientific Writing by Non-Scientists

While the authors mentioned thus far are credential-carrying scientists, there is in addition a splendid array of non-scientists, including journalists, expositors, critics of style in scientific writing, biographers, historians, and critics of modern science. Their perceptiveness and the quality of their insight demonstrate that the non-scientist can illuminate discoveries and problems precisely because of his oblique angle of vision.

Among other journalists, the scientific reporters for The New York Times, The Wall Street Journal, and The New Yorker are generally trustworthy in their scrupulous treatment of data and scientific inferences. Non-scientists are even represented in the scientific journals: Barbara Culliton and Nicholas Wade, for instance, track governmental and social policy relating to science and report regularly to readers of Science.

Some literary essayists show a profound interest in science as it relates to other cultural forms. George Steiner resists C. P. Snow's idea of two cultures. Instead, he finds two orientations, one bearing "the overburdening luggage of the past," the other looking ahead; in fact, "the energies, the gaieties, the moral tensions, so often lacking in our rather battered civilization, are present in the life of science." [18] In Science and Imagination Marjorie Hope Nicholson describes John Donne's interest in astronomy and Johann Kepler's authorship of a dream tale, "Somnium." B. P. Medawar finds a correspondence between scientific and literary creation:

> "All advance of scientific understanding, at every level, begins with a speculative adventure, an imaginative preconception of what might be true..The conjecture is then exposed to criticism.. Scientific reasoning is therefore at all levels an interaction between two episodes of thought, a dialogue between two voices, the one imaginative and the other critical..between what might be true and what is in fact the case..."[19]

Critics who find scientists setting themselves above the rest of society

counter such effulgence. George Gale, editor of The Spectator, accuses scientists of assuming themselves to be a race apart, at least intellectually.[20] More recently, Richard Wear in The Chronicle of Higher Education labels the scientific-technological segment of our society "the new Carthaginians" for their inordinate claims on the nation's resources, as he argues for a broader education in the humanities than science major students are usually afforded.[21] Lord Ritchie-Calder discussed recently the international implications of the fact that the structure of science is largely a Western creation.[22]

Writing specialists provide fascinating discussions of style in scientific writing. A comprehensive survey and commentary by Steve Aaronson in Current Contents deplores clumsy jargon but is primarily directed toward describing the characteristics of good style and their special significance to scientific writing.[23] A poet, Elizabeth Sewell, has written an absorbing account of the use of metaphor in scientific research.[24]

Of the biographies and philosophical commentaries by non-scientists, a wide selection is available by authors whose reputation for good research and literary excellence has been established. Andre Maurois's The Life of Sir Alexander Fleming and Marc Belth's The Process of Thinking are fine examples.

Significance of Humanistic Scientific Writing in Education

Scientific writing beyond the circumscribed style of textbooks provides for the student an opportunity to see the scientist as a human being, to find a means of communication with him, to see science as a method of discovery, and to make judgments that can be translated into social, political, and personal action.

The educated man must be disabused of his ambivalence toward science, his intermingled idolatry and distrust. Philip Abelson, editor of Science, has

stated the problem succinctly: "The public has the impression that scientists, engineers, and physicians are not delivering the perfect performance that should be expected of them."[25] Both idolatry and distrust are anti-intellectual, preventing a rational analysis of the scientist's contributions while arrogating to him a power that should be feared by the populace and rejected by the scientist.

The idolatry derives from the naive belief that the scientist is the new Prometheus, with power beyond the common ability to discover secrets of such magnitude that they defy human control. It implies confidence in these secrets as truth not created by but revealed to the scientific mind and therefore invulnerable to rational analysis. Scientists, as Lord Ritchie-Calder notes, "are like the craft guildsmen of the Middle Ages: they have their 'mysteries,' their rituals, and their sign language."[26]

The corrective for unreasonable awe is first, recognition of the role of human intellectual processes in scientific discovery. Max Planck, for instance, states that "It is impossible...to assert that any science possesses a structure evolving from its own nature inevitably,"[27] and Mark Slade provides an example: "Copernicus did not pluck our planet from the centre of the universe and set it somewhere on the periphery. He plucked at men's senses, at their beliefs, at the way each person saw himself in relation to a cosmic environment."[28] Of particular interest to non-scientists is the role of language--human, not supra-human language--in the construction of scientific knowledge. Bronowski, Sewell, Nicholson, and Thomas Kuhn all demonstrate how scientists speculate on new phenomena by comparing them with known phenomena. The scientists' selection of simile and metaphor is a human and comprehensible activity analagous to the selection of simile and metaphor in other aspects of life. Other writers such as Marc Belth reinforce the significance of

linguistic manipulation in cognitive activities:

> "It is some human being who gives classifying labels to nature, for purposes of identification, tracking, communication, explaining and predicting...The language, that is, the labels themselves, become part of the matter of investigation... The data are transformed by the models we borrow or construct, in the full awareness that as the inquiry proceeds, not only may the models of analysis alter, but in that altering the subject matter itself may alter."[29]

Second, unreasonable awe can be mitigated by understanding the scientist as a human being, governed by the emotions and search for personal meaning that direct the rest of us. Reading the scientists' own accounts of their journeys into the unknown and their social and philosophical concerns facilitates such an understanding. How can one remain remote from Pasteur when he writes, "To bring one's self to believe in a truth that has just dawned upon one is the first step towards progress; to persuade others is the second. There is a third step, less useful, perhaps, but highly gratifying, nevertheless, which is to convince one's opponents."[30] Through reading the scientists, one can observe what is common to scientist and non-scientist alike.

Distrust of scientists may be as anti-rational as idolatry. Bronowski protests the thoughtlessness of the charge that scientists are indifferent to morality, but Monod concedes its pervasiveness: "...this anxiety, this deep-lying mistrust that most of our contemporaries possess before the modern world and science itself is a feeling of alienation which is far from being confined to the least cultivated..."[31] Mistrust of science as a "thing" transfers to scientists as persons and has not diminished with the advance of education. As late as 1977 the editor of Change saw it as a new feeling and Ritchie-Calder as a feeling of the new generation. "There is a new antiscience bias in the air, often informed more by emotion than by fact, and a growing

suspicion of what the scientists are really up to,"[32] wrote George Bonham. Ritchie-Calder saw the international implications of the belief that the combined power and amorality of scientists are leading us down a dark path toward destruction or at least toward an Orwellian loss of independence:

> "...there is a disenchantment and even a distrust of science and technology. Ironically in the highly developed countries which have most of the material benefits, there are cries of dissatisfaction. The younger generation sees science, or at least technology, as threatening the quality of life and the environment. They are contracting out. This is bad, because if science is to properly used, it must be understood.
>
> In the less developed countries there has come a growing disenchantment with science and technology, or at least with the application to real needs and rising expectations. In many cases there has been resentment of their conditions of dependency and of the way in which the transfer of technology has operated."[33]

Thus, a belief that the scientists are beyond our control has social and political implications. From international organizations to local governments, decisions are continually being made about energy, armaments, health, territoriality, and even genetic research. The citizen will not participate in these decisions if he believes that they are already beyond his control because such decisions are essentially matters of "science." If he takes instead a rational view of the scientist, he is more likely to consider himself an equal partner and make known his views through his vote, affiliations, representations to the decision-makers, even his response to public opinion polls.

Another unhealthy reaction to the scientist is philosophical and religious uneasiness. Max Planck mentions "the considerable number of religious dogmas to which physical science has dealt a fatal blow"[34] and Barzun shows the result.

> "...Western society today may be said to harbour science like a foreign god, powerful and mysterious. Our lives are changed by its handiwork, but the population of the West is as far from understanding the nature of this strange power as a remote peasant of the Middle Ages may have been from understanding the theology of Thomas Aquinas."[35]

Not only epistemology but the definition of life itself and belief about what lies beyond our senses have been influenced by the work of scientists.

But the scientists themselves, as the reader discovers, are not immune from doubt and disagreement nor impervious to faith. Naomi Bliven, in a comparative review of Jacques Monod's Chance and Necessity and Arthur Koestler's The Roots of Coincidence, notes that their views "of life and the universe are totally at odds with each other," and comments that the scientists quoted by Koestler "seem appalled at what science has done to the faiths of our (and their) forefathers."[36]

The antidote to philosophical bewilderment caused by irrational fears of science is strong medicine: to read the scientists who have searched for answers to fundamental human questions, and by reflecting on them to realize that scientists doubt, disagree, and reach their personal reconciliations with nature. Einstein, indeed, found his personal faith through science.

> "A knowledge of the existence of something we cannot penetrate, our perceptions of the profoundest reason and the most radiant beauty, which only in their most primitive forms are accessible to our minds--it is this knowledge and this emotion that constitute true religiosity; in this sense, and in this alone, I am a deeply religious man. I cannot conceive of a God who rewards and punishes his creatures, or has a will of the kind that we experience in ourselves. Neither can I nor would I want to conceive of an individual that survives his physical death; let feeble souls, from fear or absurd egoism, cherish such thoughts. I am satisfied with the mystery of the eternity of life and with the awareness and a glimpse of the marvelous structure of the existing world, together with the devoted striving to comprehend a portion, be it ever so tiny, of the Reason that manifests itself in nature."[37]

While voicing this as a personal creed he sees it extending to other scientists: "While it is true that scientific results are entirely independent from religious or moral considerations, those individuals to whom we owe the great creative achievements of science were all of them imbued with the truly religious conviction that this universe of ours is something perfect and susceptible to the rational striving for knowledge."[38]

Einstein is credited with facilitating a reconciliation between religion and science: "Einstein's thinking represents the beginning of a fifth and new revolution in scientific and religious thought. It may give us a way to save religion from a reaction against scientific thought and to open avenues for religious speculation and creativeness."[39] The layman can become aware, through dialogue with self or others, that <u>every</u> human being has the moral authority to make rational choices among the philosophies of life and develop his own faith.

The educated man does not live by textbooks alone, in science any more than in other fields. By reading beyond the science textbook, the student discovers:

(1) That scientists are not a race apart: They use empirical method, language to formulate as well as express ideas, and imaginative musings--all akin to method, language, and imagination familiar to the rest of us. Marc Belth describes the "model" that provides order to the development of any discipline:

> The model (or the analogy or the metaphor), then, gives us the language, symbols, and notational systems we use in making a description of something, an explanation of its existence and behavior. The model, the analogy, and the metaphor make it possible for us to follow out some event in the world and provide us with the possibility of attaining knowledge and understanding. It is from some model that we derive the instruments for whatever explorations or observations we make, and the judgments with which we conclude.[40]

And even the "scientific method" is neither tidy nor involunerable to error. Scientific research is beset with stops and starts, unproductive bypaths, and some apparently aimless conjecture, even as other human endeavors. Thomas Kuhn illustrates discrepancy in a model as the prelude to new thinking, as he relates the discovery of oxygen and x-rays but surely the historian could call to mind similar experiences:

> In both cases the perception of an anomaly--of a phenomenon, that is, for which his paradigm had not readied the investigator--played an essential role in preparing the way for perception of novelty. But again in both cases, the perception that something had gone wrong was only the prelude to discovery.[41]

(2) That scientists are not unconcerned about the results of their work and its effect on others, as their literature and organizations testify. (The most striking example of scientific awareness of public concern today is in the debate over DNA research.) Among scientific organizations with social goals is the Federation of American Scientists, which was founded in 1946 as "a national organization of natural and social scientists and engineers concerned with problems of science and society." They call their newsletter "the voice of science on Capitol Hill."[42] The Scientists Institute for Public Information recruits members by declaring that governmental and industrial decisions extend "far beyond the expertise of the scientists...Only the public can decide."[43]

(3) That scientists wield enormous power on at the will of society. Bonham's Change editorial concludes: "And whether scientists like it or not, both the size of the science establishment and the future direction of science are now clearly public as well as scientific issues...We agree with Hans Morgenthau that 'the scientists' monopoly of the answers to the question of the future is a myth."[44] George Gale strongly affirms that "a scientist is just as accountable for what he does and its likely consequences as

anybody else."[45] Indeed, scientists themselves claim that the needs of society shape the direction of science, and place responsibility on the citizen. Ehrlich writes:

> If the scientific community has any responsibility in this area, it is to help convince the public that important social decisions should not be made by various 'experts,' and that experts can be wrong and dishonest like anyone else. Any person with a high school education who is willing to put in some effort can learn enough of the pertinent science to make a sound judgment on most of the science-society issues of the day, if scientists are willing to explain the issues rather than take a 'trust me, I know best' stand.[46]

Cousteau is more pithy: "The average citizen can rely only on his own judgment; his civic duty is to give utterance to that judgment by all means and as loud as he can."[47]

(4) That conscientious scientists strive to communicate. Few creators wish to sequester their creations. "In all territories of thought in which science and philosophy can lay claim to...no one who has something original or important to say will willingly run the risk of being misunderstood,"[48] writes Medawar. Just as Jean-Paul Sartre avows that "There is no art except for and by others,"[49] Bronowski finds that appreciation by others is indispensable to creation.[50]

But appreciation and communication will not just happen. Because of a popular attitude that the scientific mind is unreachable, educators in every academic area should make a committment to lead their students to literate scientific writing and follow the reading with discussion of its implications. The obligation can be met, fortunately, in curricula of the physical sciences, social sciences, and humanities, for among the most authoritative scientific writers are the most articulate, and the cognitive relationships among disciplines are clear and strong.

All the reasons for studying science are also reasons for reading beyond the textbook. The teacher who provides for intelligent and selective reading and discussion makes a substantial contribution to his students' understanding and use of a dominant force in modern society.

NOTES

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[3]Barzun, op. cit., p. 11.

[4]Bondi, Hermann, "Why Scientists Talk," in The Languages of Science, (Greenwich, Conn.: Fawcett Publications, Inc., 1966), p. 51.

[5]Handler Philip, ed. Biology and the Future of Man (N.Y.: Oxford University Press, 1970), p. vii.

[6]Quoted in Bernstein, Jeremy, "Books: From Quarks to the Cosmos," The New Yorker, September 19, 1977, 137.

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[8]Sakharov, Andrei D. Progress, Coexistence & Intellectual Freedom (N. Y.: The New York Times Company, 1968), p. 84.

[9]Cloud, Wallace, "The Darkening Sea," The Sciences, 13:6-12, November, 1973.

[10]Ehrlich, Paul R., "Ecologists, Ethics, and the Environment," Editorial in Bioscience, 27:239, April, 1977.

[11]Cousteau, Jacques-Yves, "The Ocean, Survival, and the Pursuit of Happiness," Saturday Review, Nov. 27, 1976, 54.

[12]Bates, Marston. The Forest and the Sea (N.Y.: Random House, 1960), p. 254.

[13]Ibid., p. 257.

[14]Einstein, Albert and Infeld, Leopold. The Evolution of Physics (N.Y.: Simon and Schuster, 1938), p. 313.

[15]Einstein, Albert. Out of My Later Years (N.Y.: Philosophical Library, 1950), p. 60.

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[17]Toulmin, Stephen. Foresight and Understanding (N.Y.: Harper & Row, Inc., 1963), p. 33.

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[19]Medawar, B. P. The Hope of Progress (London: Methrun & Co., Ltd., 1972), p. 22.

[20]Gale, George, "Are Scientists Different?" New Scientist, 6 July 1972, 10-12.

[21]Wear, Richard, "Beware the New Carthaginians," The Chronicle of Higher Education, XV:32, Sept. 12, 1977.

[22]Ritchie-Calder, Lord, "Science Is For All," The Center Magazine, X:2-11, March/April 1977.

[23]Aaronson, Steve, "Style in Scientific Writing," Current Contents, 1977, 6-15.

[24]Sewell, Elizabeth. The Human Metaphor (Notre Dame: University of Notre Dame Press, 1964).

[25]Abelson, Philip H., Editorial, Science, 191:29.

[26]Ritchie-Calder, op. cit., 5.

[27]Planck, Max. The Philosophy of Physics (N.Y.:W. W. Norton & Company, Inc., 1936), p. 11.

[28]Slade, Mark. Language of Change: Moving Images of Man (Toronto: Holt, Rinehart and Winston of Canada, Inc., 1970), p. 4.

[29]Belth, Marc. The Process of Thinking (N.Y.: David McKay Co., 1977), pp. 188-89.

[30]Pasteur, Louis, "The Physiological Theory of Fermentation," Scientific Papers: Physiology, Medicine, Surgery, Geology, vol. 38, The Harvard Classics (N.Y.: P. F. Collier & Son Corp., 1938), p. 345.

[31]Monod, Jacques. From Biology to Ethics (San Diego: Salk Institute for Biology Studies, 1969), p. 2

[32]Bonham, George W., Editorial, "Is Science Good Enough?" Change, 9:11, June, 1977.

[33]Ritchie-Calder, op. cit., 9.

[34]Planck, op. cit., 10.

[35]Barzun, op., cit., 10.

[36]Bliven, Naomi, "Head to Head," The New Yorker, Aug. 12, 1972, 76.

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[38]Ibid., p. 52.

[39]Laws, John W., "Toward a Theory of Nature," Intellect, May-June, 1975, 534.

[40]Belth, op. cit., p. 29.

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[42]F. A. S. Newsletter.

[43]Membership letter, Scientists' Institute for Public Information, 1972.

[44]Bonham, op. cit., p. 11.

[45]Gale, op. cit., p. 12.

[46]Ehrlich, op. cit., p. 239

[47]Cousteau, op. cit., p. 54.

[48]Medawar, op. cit., p. 29.

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